SOME NEW BOOKS.

Great Astronomers.

The Messrs. Macmillan have published in book form a remarkable series of lectures delivered by Prof. OLIVER LODGE at the University College, Liverpool. The title *Pioneers of Science* is somewhat too broad for the contents of the volume, for the author confines himself to describing in popular language the great achievements in astronomy and the men by whom they have been made. Beginning with Copernicus and Tycho Brahe, Mr. Lodge proceeds to Kepler and Galileo, next to Descartes and Newton, and so on to Roemer and Bradley, Lagrange and Laplace, Herschel and Bessel. Other lectures deal with the discovery of the asteroids and that of Neptune, with comets and meteors, and finally with the tides and planetary evolution.

I.

Nicolas Copernik, better known by the Latinized form of his name, Copernicus, is believed to have been a German, although he was born at Thorn in Polish Prussia and graduated at Cracow University. He was instructed in astronomy at Cracow, and learned mathematics at Bologna. Thence he went to Rome, where he was made professor of mathematics, and soon afterward he went into orders. On his return home he took charge of the principal church in his native place, and afterward moved to Frauenburg, near the mouth of the Vistula, where he spent the rest of his life. It is noteworthy that to Polish Prussia we owe the earliest of modern astronomers as well as the greatest of modern philosophers, Kant.

Copernicus was a quiet, scholarly monk whose life was passed in study and meditation. His first work in astronomy was the compilation of tables of the planetary motions, which were far more correct than any which had hitherto appeared, and which remained serviceable long afterward. The Ptolemaic system of the heavens which had remained the orthodox conception throughout the Christian era, he endeavored to improve and simplify by the hypothesis that the sun was the centre of the planetary system instead of the earth. The first consequences of this change he wrought out for many years, producing in the end the famous work "On the Revolutions of the Celestial Orbs," which embodies all his painstaking calculations, and applies his new theory to each of the bodies in the solar system. Not until the very end of his life was the book put into type, but a printed copy was brought to his bedside so that he might feel it before he died.

The revolutionary consequences of his hypothesis were not appreciated at the time, partly because his teaching was buried in a ponderous and technical treatise, partly because the teacher was an ecclesiastic, mainly because he was a patient and judicious man, content to state his views in quiet conversation and let them gently spread for thirty years before he published them. When he did publish them he dedicated his book to the Pope, and induced a Cardinal to bear the expense of printing. Thus the Roman Church was made to stand sponsor to a system of astronomical doctrine against which in the next century it was destined to hurl its anathemas and the most conspicuous adherents torture, imprisonment, and death. The achievement of Copernicus may be summed up in a sentence. He demonstrated the truth of a theory said to have been taught by the Pythagoreans and Aristarchus, which had against it the great weight of Aristotle's authority and which was new to the modern world. He put the sun in its true place as the centre of the solar system; he greatly simplified the theory of planetary motions by this step; he exhibited the precession of the equinoxes (discovered by Hipparchus) as due to a conical motion of the earth's axis; and by means of a simpler theory and more exact planetary tables, he reduced to some sort of order the confused chaos of the Ptolemaic system. Copernicus himself felt the hypothesis of the motion of the earth to be a difficulty. Mr. Lodge points out that its acceptance is by no means such an easy and childish matter as we are apt now to regard it, and the hostility to it is not at all surprising. The majority of the men of the present day have grown accustomed to hear the motion of the earth spoken of; their acceptance of it means nothing; the attitude of the paradoxer who denies it evinces more intelligence. The author acknowledges for himself that it was a long time before he could realize the revolution of the earth. Think, he says, of the solid earth, with trees and houses, cities and countries, mountains and seas—think of the vast tracts of land in Asia, Africa, and America—and then picture the whole mass spinning like a top and rushing along its annual course around the sun at the rate of nineteen miles a second. Then, again, to imagine a possible antipodes must have been a tremendous obstruction in the way of conceiving the earth as a sphere. Mr. Lodge has found that intelligent children invariably feel the greatest difficulty in realizing the existence of inhabitants on the opposite side of the earth. Of course, stupid children, like stupid persons in general, will believe anything they are told; but the kind of difficulties felt by intelligent and thoughtful children are most instructive, since it is certain that the early philosophers must have encountered and overcome these very same difficulties by their unaided genius.

Nor are the difficulties involved in the conception of the earth as a sphere revolving round the sun only physical; they are still more felt from the speculative and theological points of view. Even now the reconciliation of theology with astronomy can hardly be considered complete. Theologians, indeed, do not deny the fact of the extreme subordination of the earth in the scheme of the universe, but many of them ignore it. So soon as the Roman Church awoke to a perception of the tremendous and revolutionary import of the doctrines of Copernicus, it was bound either to resist them or else to be false to its traditions. For the whole tenor of men's thought would be changed if they accepted it. If the earth were not the central and all important body in the universe, if the sun and planets and stars were not attendant and subsidiary lights, but were other worlds larger, and perhaps superior to ours, where was man's place in the cosmos, and where were the doctrines which the Church had maintained to be irrefutable? It was not to be expected that such a revolution would be accepted in a day, or in a century; and the plan naturally adopted by the Church was to treat it as a heresy and try to crush it out.

Inasmuch, moreover, as scientific progress was vastly slower in the sixteenth century than it is now, not only all priests, but even many astronomers, one hundred years after Copernicus, still imagined the earth to be at rest. Among the men of science who still adhered to the Ptolemaic system, although he was born three years after the death of Copernicus, was Tycho Brahe. By birth a Danish noble, he was sent to the University of Copenhagen to study law, but was attracted to astronomy by the occurrence of an eclipse on the predicted day. He began to construct astronomical instruments, and produced a quadrant and a sextant. With funds provided by the King of Denmark, he built Uraniburg, the first modern observatory, provided it with means of accurate observation not equaled at the time or for long afterward, and became the founder of instrumental astronomy. His theories were poor, but his observations were admirable. He introduced a precision in mensuration before undreamed of, and though his measurements according to modern ideas are ludicrously rough (no such thing as a telescope or a microscope having been invented), yet, in view of the era at which they were made, they are marvels of accuracy, and not a single mistake due to carelessness has ever been detected in them. For certain purposes connected with the proper motion of the stars they are still appealed to, and they served as trustworthy data for several succeeding generations of theorists to work upon. It was long, indeed, after Tycho's death before observations approaching in precision to his were made. In the true sense of the word he was a pioneer.

II.

If everything else that he did were forgotten, Tycho Brahe would still be remembered as the teacher of Kepler. The son of a poor officer in the army of the Duke of Würtemberg, he was at first a tavern pot boy, but was ultimately sent to a charity school and thence to the University of Tübingen. He studied mathematics and accepted an astronomical lectureship at Graz. In 1597, at the age of 26, he published his first fanciful hypothesis, by which he endeavored to discover some connection between the number of the planets, their times of revolution, and their distances from the sun. Two years later he was invited by Tycho Brahe to Prague, whither the Danish astronomer had retired from his native country. After incredible labor, through innumerable wrong guesses, and six years of incessant calculation, Kepler at length emerged with his two first "Laws"—discoveries which swept away all epicycles, deferents, equants and other remnants of the Greek system, and ushered in the dawn of modern astronomy. These laws, it is well known, were, first, that the planets move in ellipses with the sun in one focus, and, second, that the radius vector (or line joining the sun and planet) sweeps out equal areas in equal times. Ultimately Kepler discovered the connection between the times and distances of the planets, for which he had been groping through all of his mature life. This law, which he announced in 1618, is that the square of the time of revolution (or year) of each planet is proportionate to the cube of its mean distance from the sun. His three laws, taken together, place him in the very highest rank of scientific men. They introduced order and simplicity into what would have been a chaos of the details of observation, and they served as a secure basis for the splendid fabric to be reared on them by Newton.

To realize what Kepler did for astronomy it is necessary for us to consider some science still in its infancy. Astronomy is now so thoroughly explored that it is difficult to put one's self into the attitude of the men of the sixteenth century. Let us take, then, some other science, still barely developed, like meteorology, for example. The science of the weather—the succession of winds and rain, sunshine and frost, clouds and fogs—is now very much in the condition of astronomy before Kepler. Observation is heaped on observation, tables are compiled, volumes are filled with data, the hours of sunshine are recorded, the fall of rain, the moisture in the air, the kind of clouds, the temperature; millions of facts; but where is the Kepler to study and brood over them? Where is the man to spend his life in evolving the beginnings of law and order from the midst of all this chaos? A life of such labor, crowned by three brilliant discoveries, was that of Kepler. The experimental observer is indispensable, but how backward would science be were observations not interpreted by thinkers like Copernicus, Kepler, Newton, and Laplace.

III.

A contemporary of Kepler was Galileo. The latter was born in the year 1564, in which Michael Angelo died, and he died in 1642, the year in which Newton was born. The persecution of Galileo did not begin until 1615, nor become intense until 1632; from the last named date it lasted till his death. Born at Pisa, Galileo studied medicine in the university of that city. He was an experimental observer. It was by experiment that he refuted the assertion of Aristotle that bodies fall at rates depending on their weights. Galileo, on the contrary, contended that the weight did not matter in the least, but that everything would fall at the same rate, even a feather but for the resistance of the air, and would reach the ground at the same time. To convince his opponents, he ascended one morning the famous leaning tower of Pisa, taking with him a 100-pound shot and a one-pound shot. In the presence of the assembled university, he balanced them on the edge of the tower and let them drop together. Together they fell and together they struck the ground. This victory over the Aristotelians made Galileo unpopular in Pisa, and he presently found his professor's chair untenable. Having received the offer of a professorship at Padua from the Senate of Venice he accepted it, and began a successful career. It was at Venice that Galileo invented the telescope. He had heard, to be sure, of a toy constructed by a Dutch optician out of a couple of spectacle lenses, through which, if one looked, the weather cock of a neighboring church spire was seen nearer and upside down. Galileo's instrument was made on another plan from that of the Dutch optician. He took an old organ pipe, jammed a suitably chosen spectacle glass into either end, one convex, the other concave, and thus produced the half of a wretched opera glass capable of magnifying three times. It was better, however, than the Dutchman's toy, because it did not invert. Even with this rude telescope it was possible to make ships visible from one of the highest towers in Venice two hours before they were seen entering the harbor. Subsequently Galileo succeeded in making a telescope magnifying thirty times. Equipped with this he was ready to begin a survey of the heavens. The first object he examined was the moon, where he found everything at first sight very like the earth—mountains and valleys, craters and plains. To the disgust of the Aristotelians, he not only made the moon like the earth, but he made the earth shine like the moon, explaining by earth-shine the visibility of "the old moon in the new moon's arms." One of the stock arguments against the Copernican theory of the earth being a planet was that the earth was dull and dark, and did not shine. Galileo argued that it shone just as much as the moon does, and, in fact, rather more, especially if it be covered with clouds. Seen from the moon, the earth would look exactly as the moon does to us, only a little brighter and sixteen times as big. It is noteworthy that Galileo made a very good estimate of the height of lunar mountains, of which many are five miles high and some as much as seven. Wherever in the firmament Galileo turned his telescope new stars appeared. The milky way, which had so puzzled the ancients, was found to be composed of stars. His most brilliant achievement was the discovery of the four moons of Jupiter. His opponents contended that there were more than four, but no proof of the assertion was furnished until last year, when news from the Lick Observatory made the existence of a small fifth satellite of Jupiter not improbable. It should also be remembered that Galileo invented a thermometer and a microscope. If we pass from his achievements in invention and observation to the results of study and meditation, we must regard as his weightiest performance his formulation of the laws of motion, the outcome of the application of mathematics to experiment. We have seen how he showed that all bodies fall at the same rate, except for the disturbing effect of the resistance of the air. What is this rate? The height through which a dropped body falls is not proportional to the time simply, but to what is called the square of the time, that is, the time multiplied by itself. Thus, in one second, a freely falling body near the earth is found to drop sixteen feet. In two seconds it drops sixty-four feet, that is, sixteen multiplied by the square of two. In three seconds it drops 144 feet, or sixteen multiplied by the square of three, and so on. The fact that the height through which a body falls is proportional to the square of the time, proves that the attraction of the earth or the intensity of gravity may be regarded as constant through ordinary small ranges. Through great distances gravity cannot be considered constant; under such circumstances the Galilean law of the square of the time does not hold.

Whether Bruno was executed for heresy is still disputed, but there is no doubt that he was imprisoned for teaching the plurality of worlds, the Copernican theory of the motion of the earth, and other heterodox doctrines. His death occurred in 1600, and his treatment would naturally make a deep impression upon Galileo. Nevertheless, while still a professor at Padua, and not long after Bruno's death, he threw down the gauntlet in favor of the Copernican theory, repudiating the old Ptolemaic system which up to that